Probing the Nuclei of Active Galaxies

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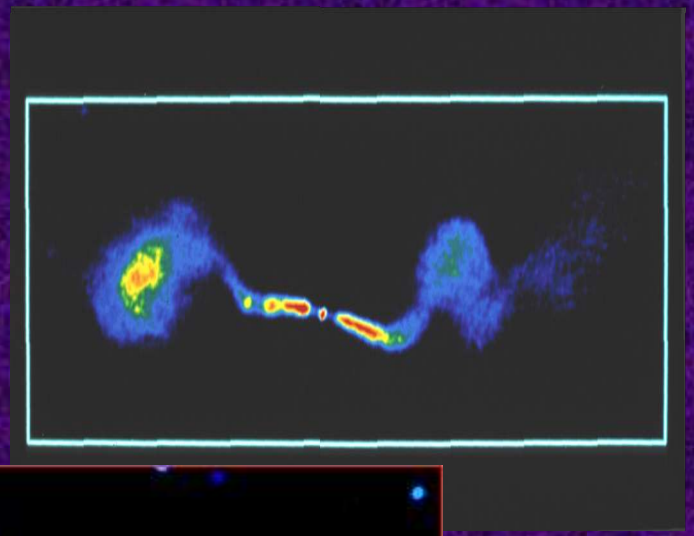
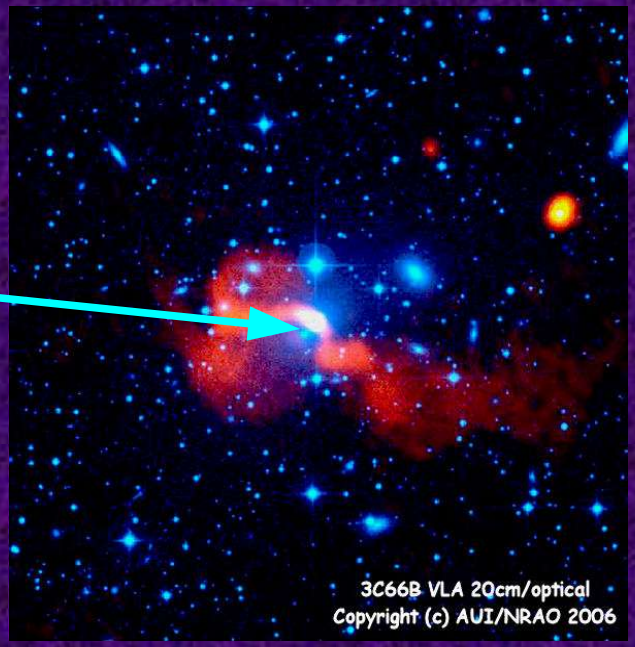
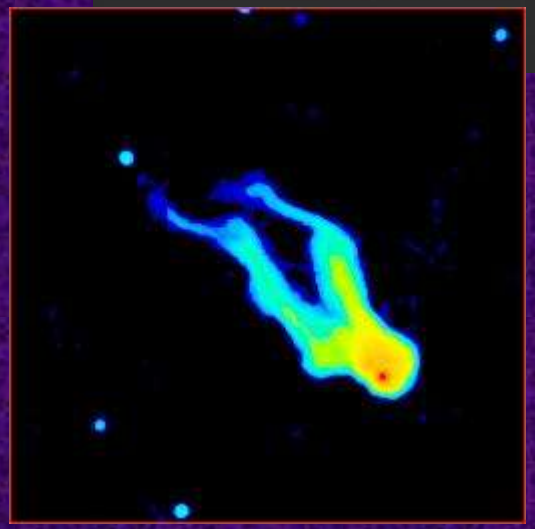
- Investigating B fields in AGN jets, especially the hypothesis that many (all?) AGN jets have helical B fields (note that then jets carry current!)
- Using Faraday effects to derive information about jet B fields and surrounding environment
- Studies of very rapid variability of compact AGN – scintillation vs. intrinsic variations
- Systematic studies of jets on wide range of scales
- Coordinated radio and optical polarization observations

Jets emerging from the centres of Active Galactic Nuclei on scales of 1000's of light years (kiloparsecs) – ultimate origin of activity is a supermassive black hole at the galactic centre



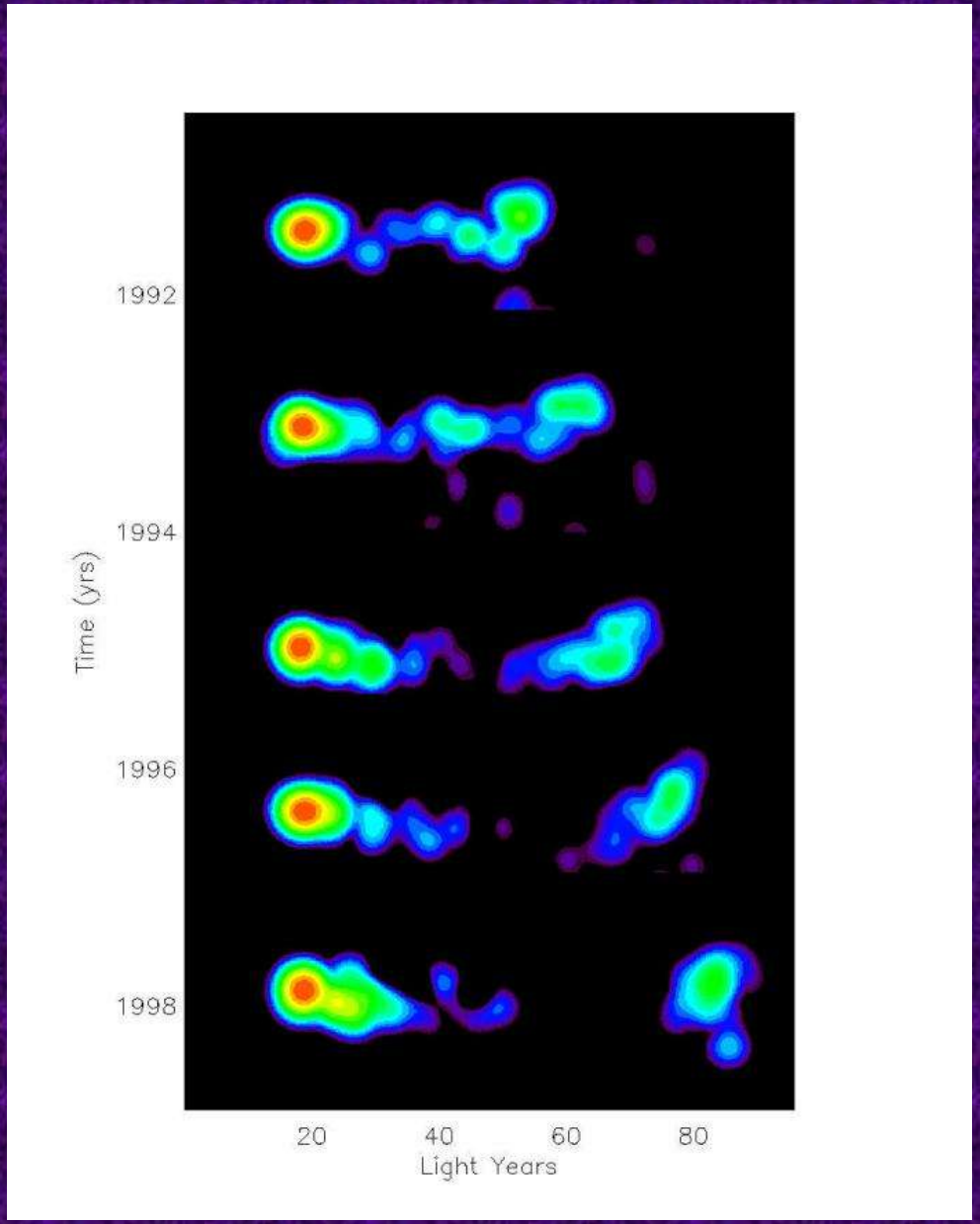
Optical galaxy





Parsec-scale jets are one-sided, due to Doppler beaming of the radio emission in the direction of motion – the approaching jet is believed to be oriented close to the line of sight.

The jets show apparent "superluminal" motions – also a geometrical effect due to the fact that the relativistic jet is moving toward the Earth at a small angle to the line of sight.



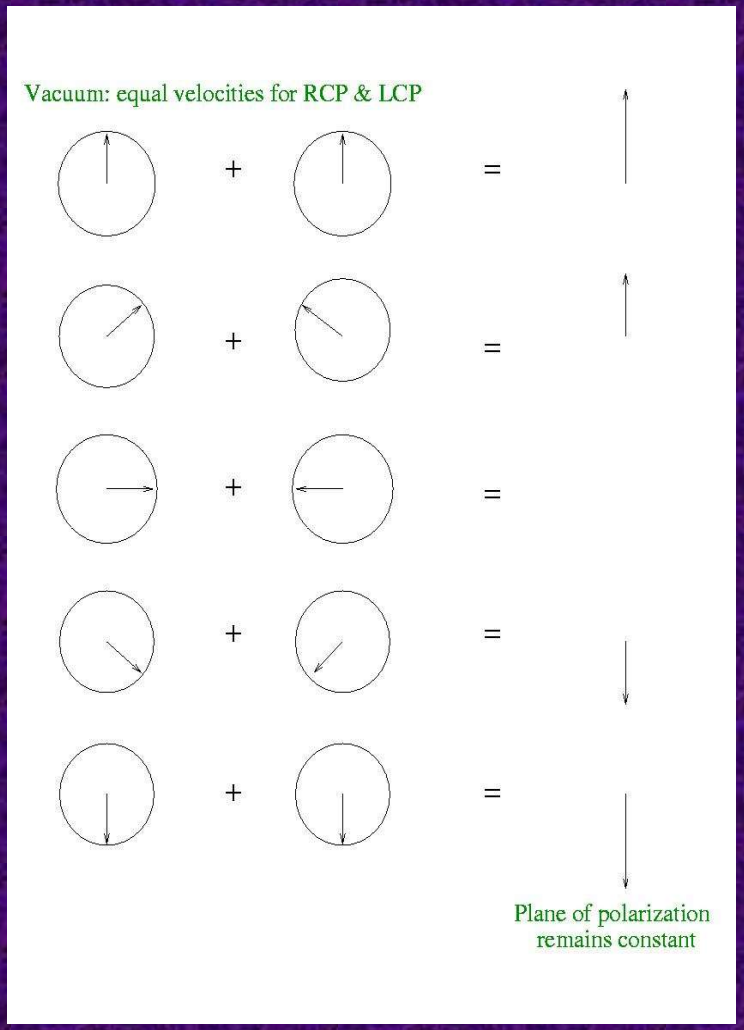
• Observed radio emission is synchrotron radiation emitted by relativistic electrons moving through regions with magnetic (B) fields

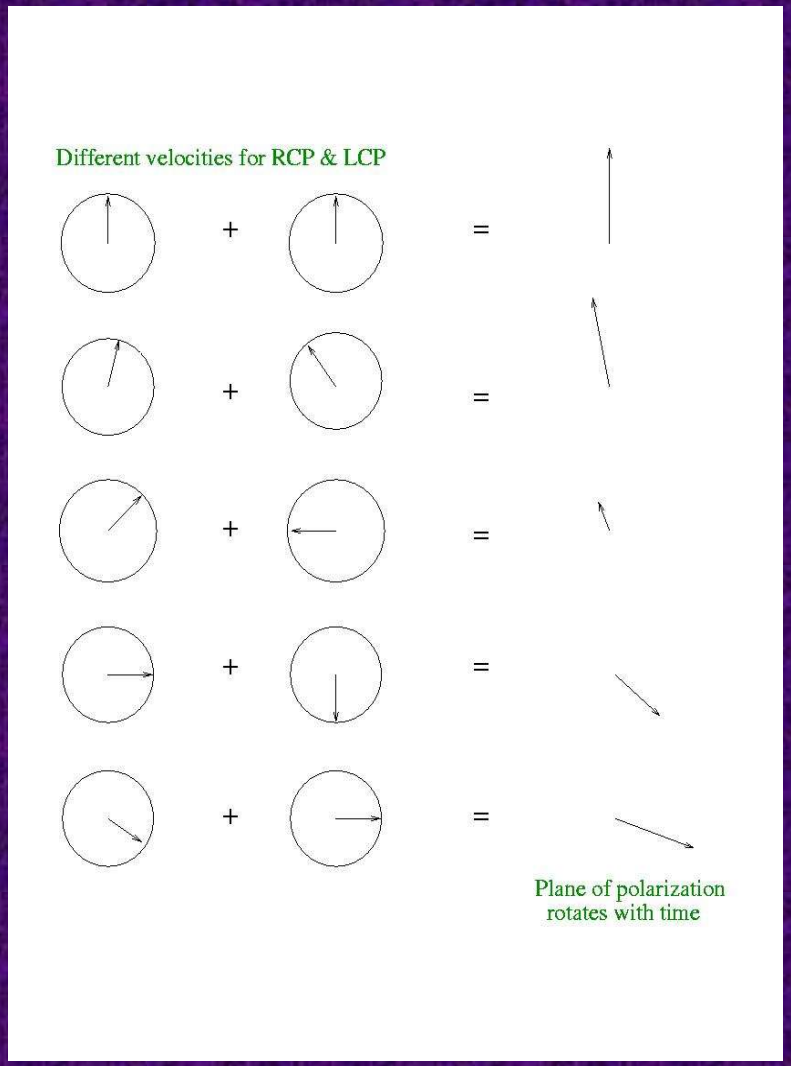
• Synchrotron radiation is highly linearly polarised (up to about 75%)

→ Degree of linear polarisation carries information about degree of order of B field

→ Plane of linear polarisation carries information about orientation of B field (the two are orthogonal when the emitting plasma is “optically thin”)

Observed polarisation angles can be affected by Faraday rotation – plane of polarisation rotates when the EM wave travels through a region with magnetised plasma – RCP and LCP components obtain different velocities



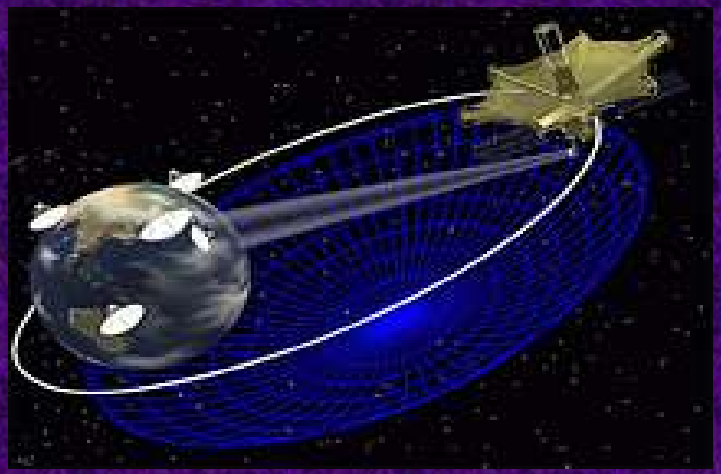


Rotation is proportional to square of observing wavelength, and also depends on integral of electron density and line-of-sight component of magnetic field from source to observer:

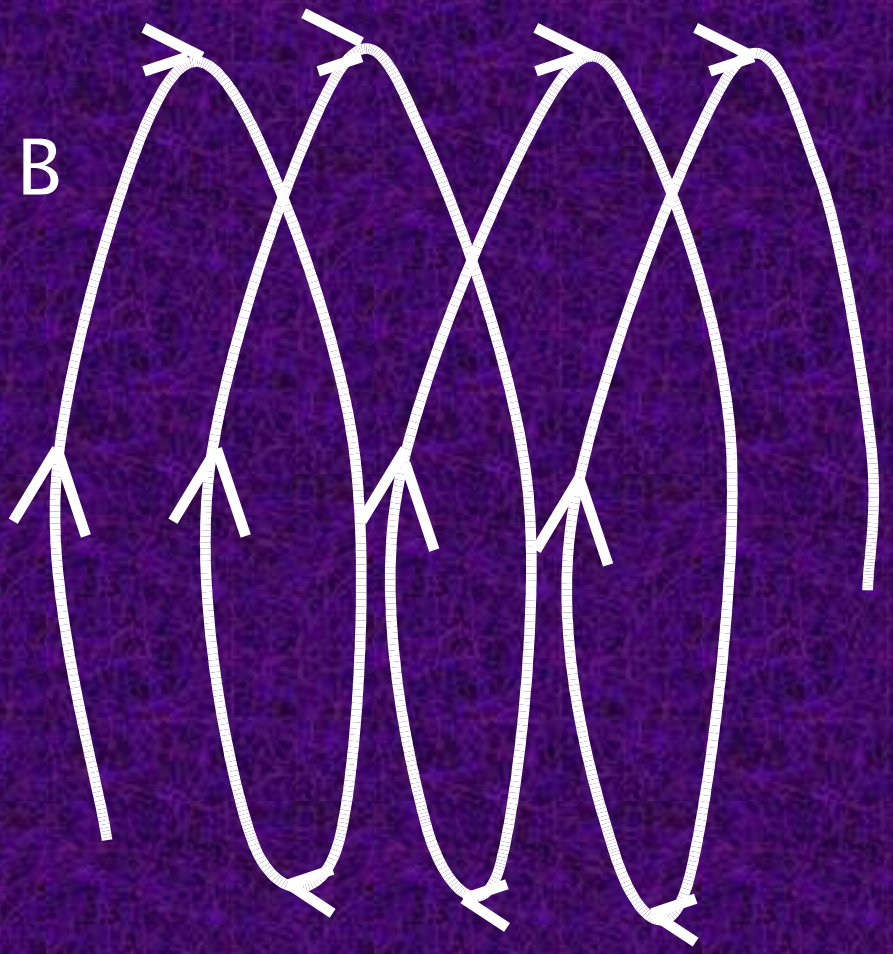
$$\text{Observed pol. angle} - \text{Intrinsic pol. angle} \propto \lambda^2 \int n \, \mathbf{B} \cdot \mathbf{dl}$$

Coefficient of λ^2 is called the “rotation measure (RM)”.

Arrays of radio telescopes used for Very Long Baseline Interferometry to achieve high angular resolution – study jets on parsec (light-year) scales



Powerful diagnostic for presence of toroidal/helical B fields: Faraday-rotation gradient *across* the jet – due to systematically changing *line-of-sight* component of B field across the jet. If jet is viewed at ~90° to jet axis in source frame:



~ Zero RM

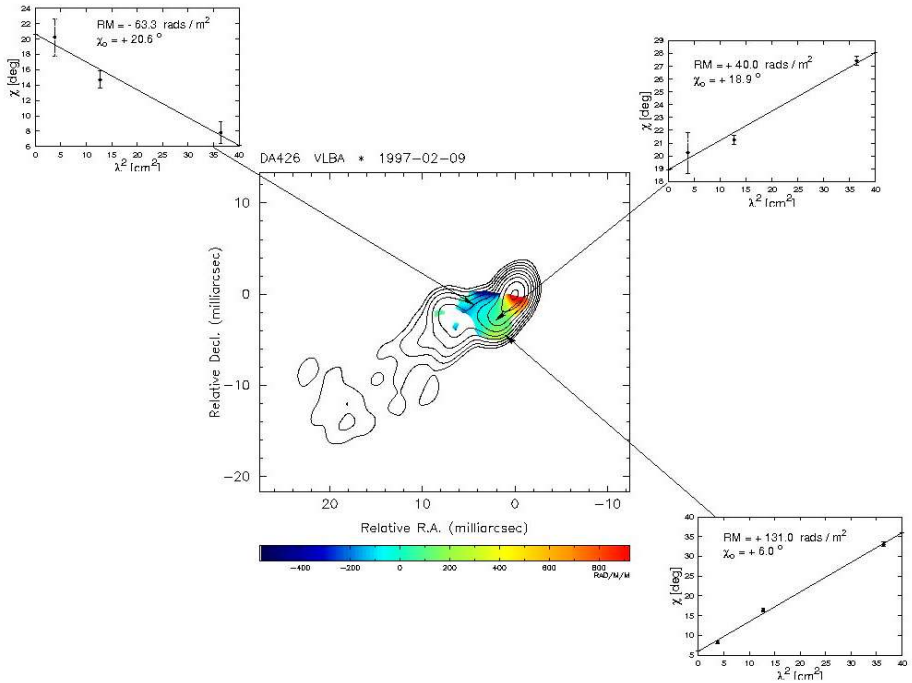
Negative RM (LOS B away from observer)

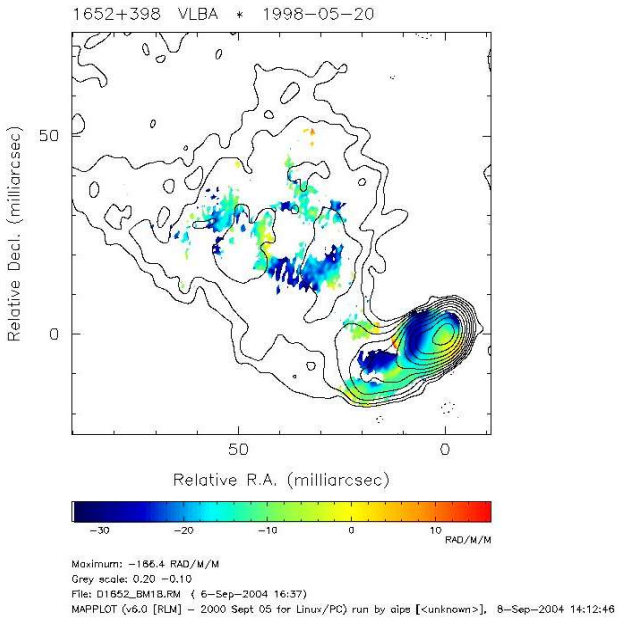
Positive RM (LOS B towards observer)

4th year project student in 2003

2nd year Summer student in 2004

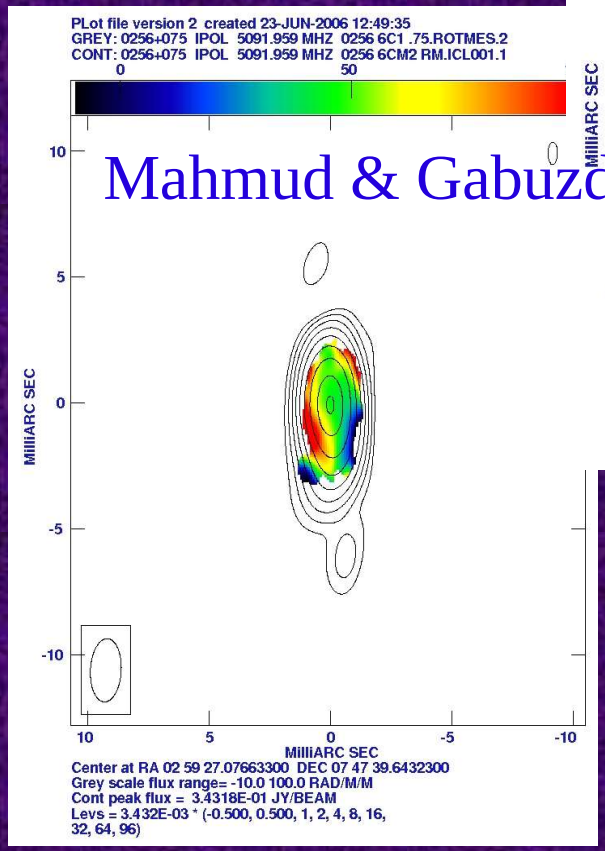
Gabuzda, Murray, Cronin 2004: Found expected behaviour for toroidal/helical B field viewed at 90º to jet axis in source frame in Mrk501



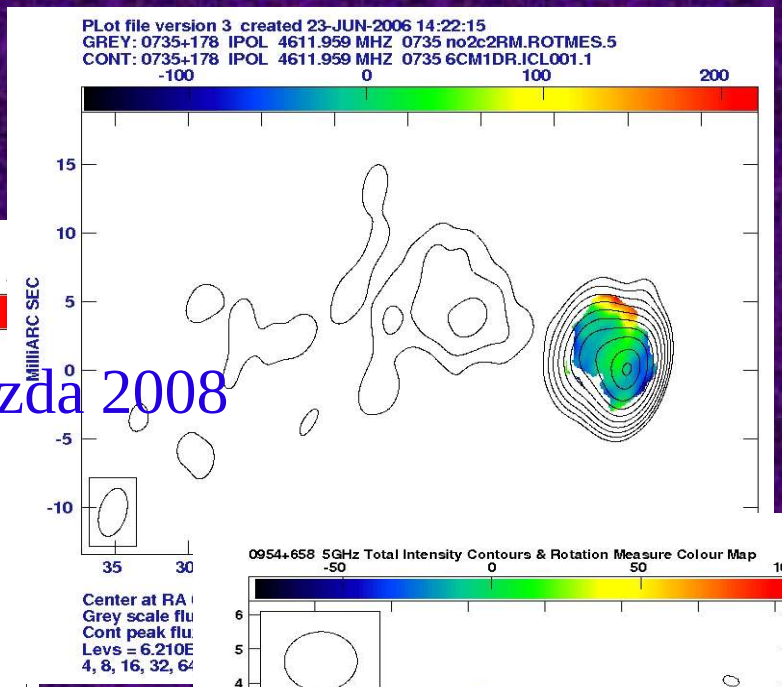


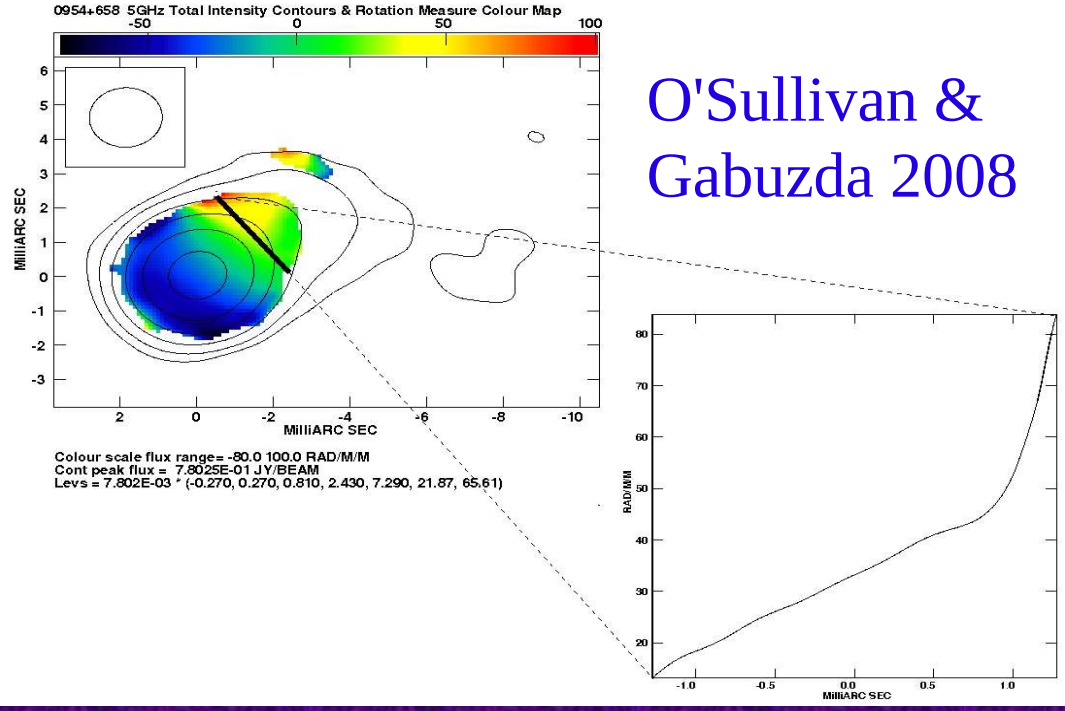
Croke, Gabuzda & Katz (in prep): RM gradient with same sense detected using 3.6+6+13+18cm VLBA data

New transverse RM gradients in several sources …



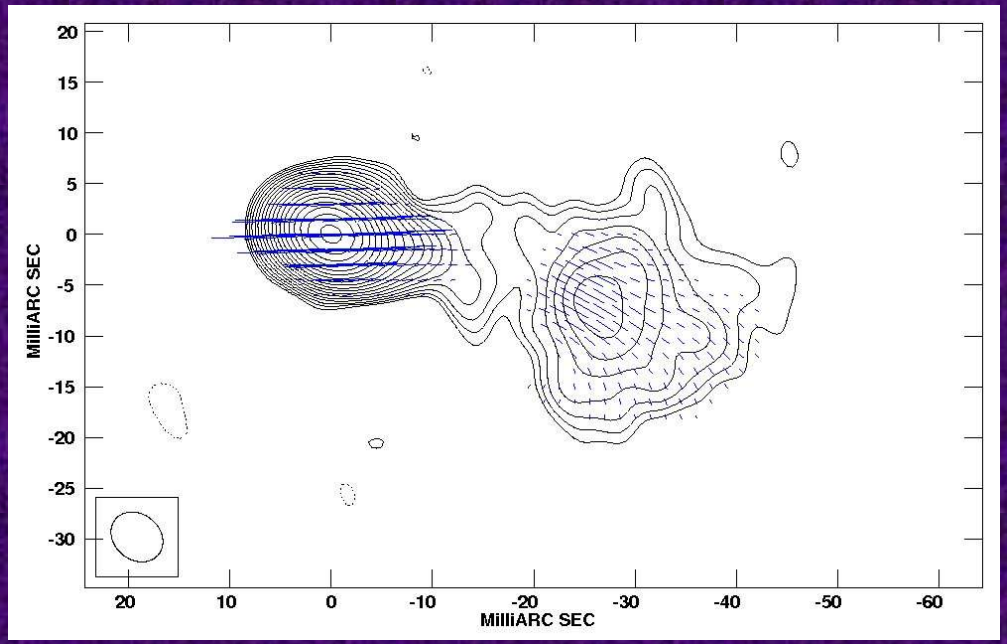
Mahmud & Gabuzda 2008





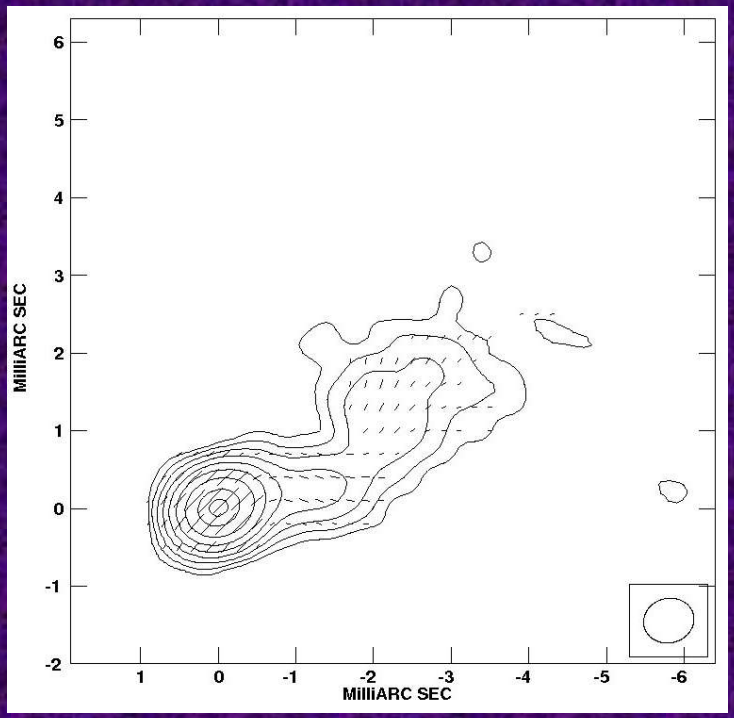
O'Sullivan & Gabuzda 2008

Other signs of helical B fields - Extended regions of transverse jet B field (aligned E vectors)

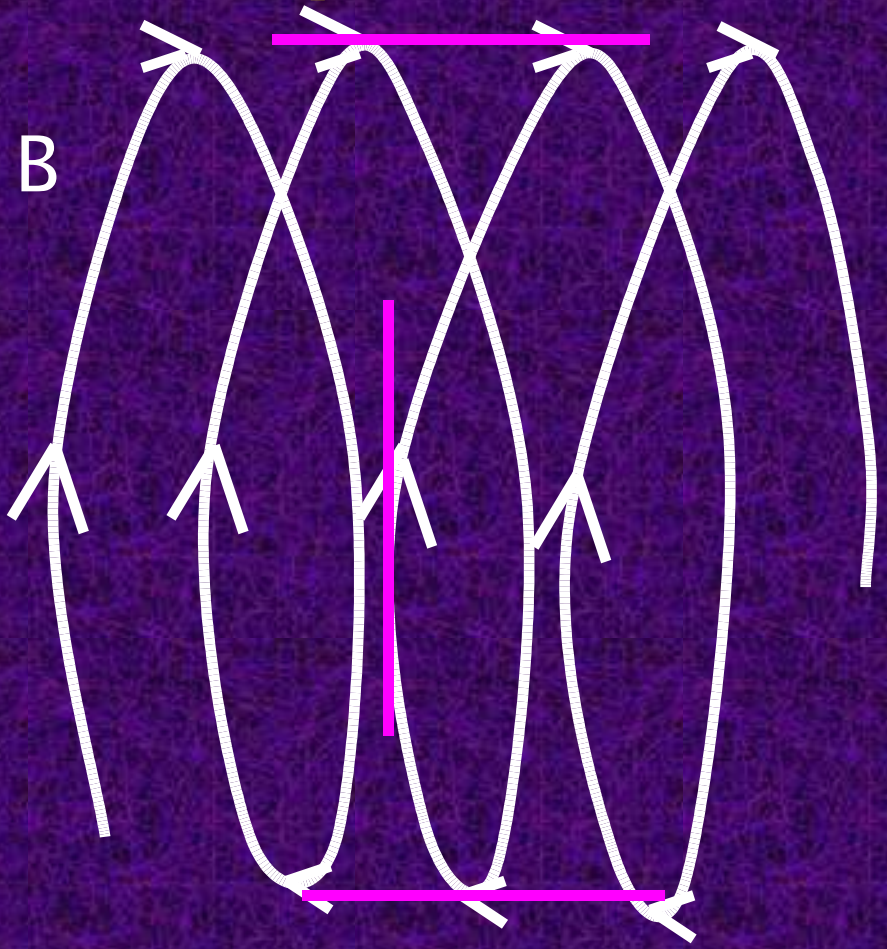


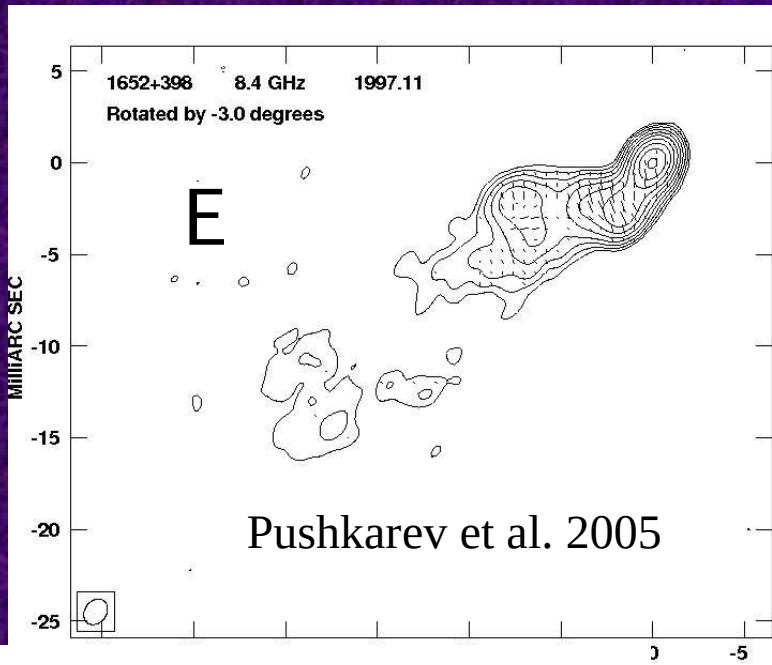
18cm VLBA map of 1803+784; Gabuzda & Chernetskii 2003

2cm VLBA map of 1749+701; Gabuzda, Lisakov & Pushkarev, in prep.

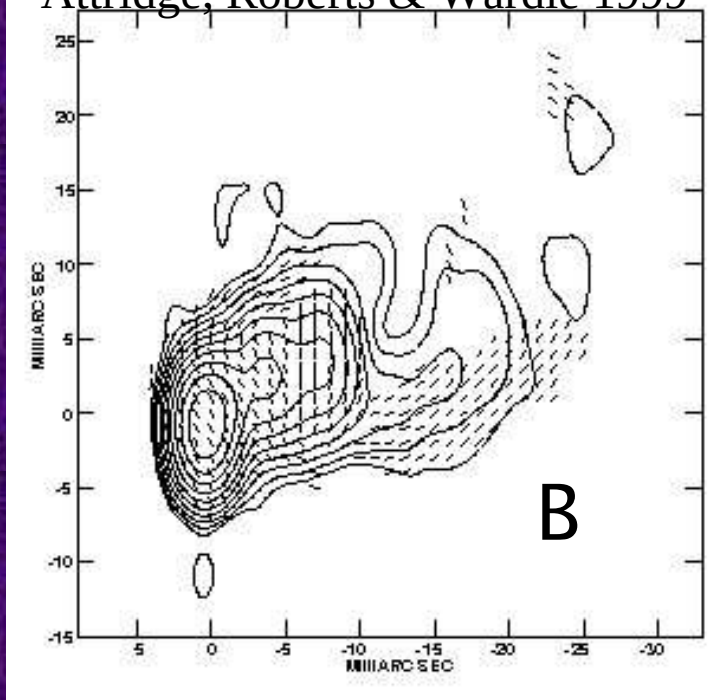


"Sheath-like" jet pol structures – maybe interaction with surrounding medium, but more natural explanation is helical B field:

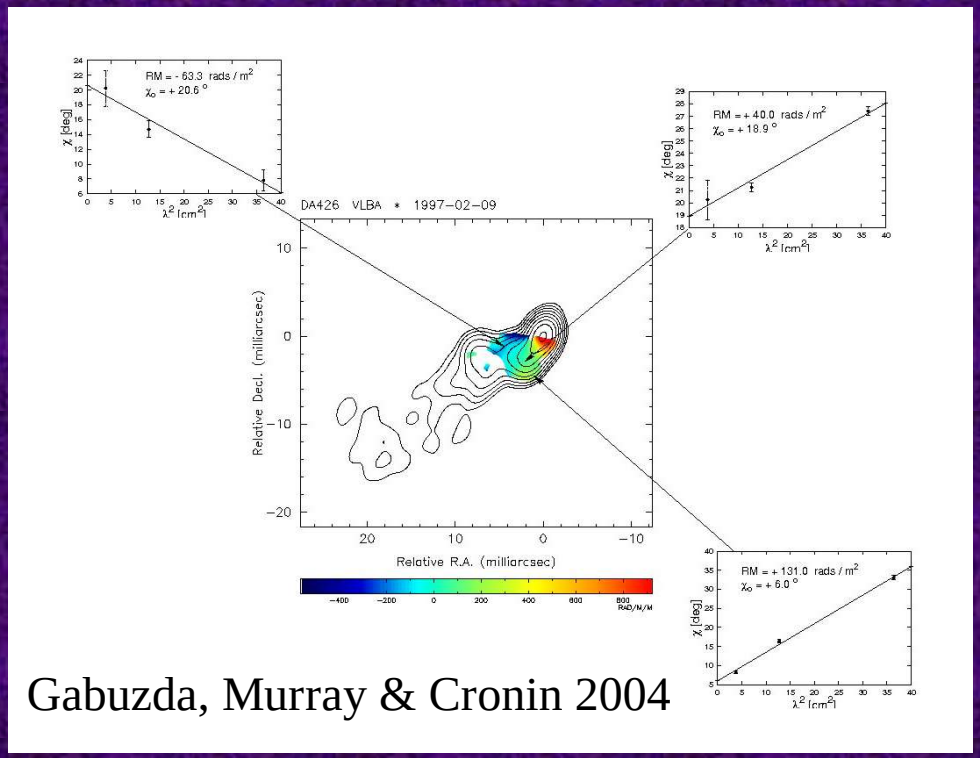




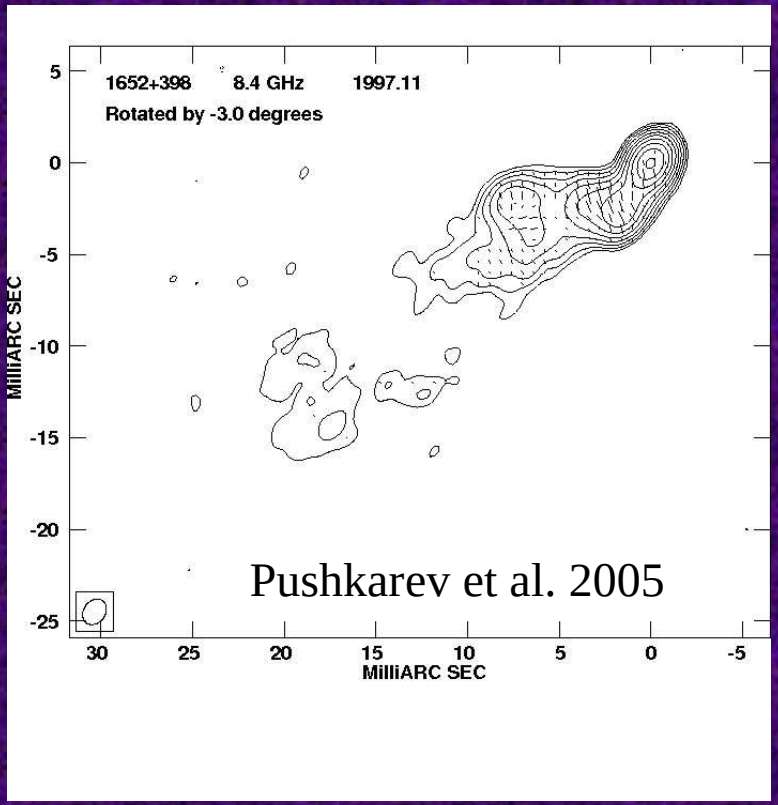
Attridge, Roberts & Wardle 1999



If polarization “sheaths” are associated with helical B fields, some sources with “sheaths” should display RM gradients as well … and they do!



Gabuzda, Murray & Cronin 2004

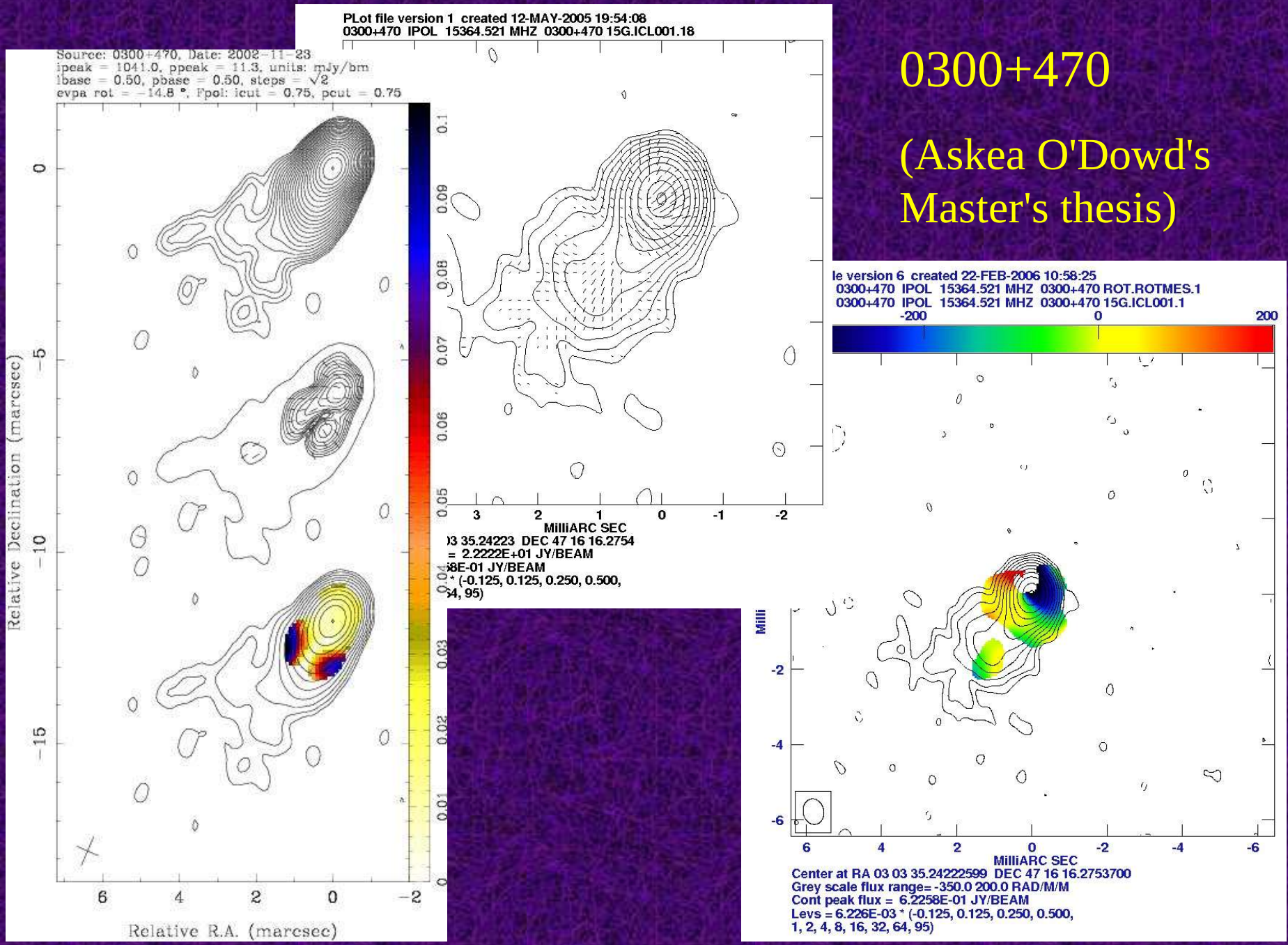


Pushkarev et al. 2005

Mrk501

0300+470

(Askea O'Dowd's Master's thesis)



Possible 4th year projects

- Deriving information about the properties of individual components/ regions in the nearby bright radio galaxy 3C111 as they rapidly evolve and move outward from the centre of activity.

- Model fitting VLBI data for the TeV AGN Mrk501 obtained at 4 epochs separated by only 3-4 weeks, to look for evidence of extremely rapid motions and polarization changes in the jet.

- Deriving information about the pitch angles of helical jet B fields and the angles of the jets to the line of sight by calculating transverse Faraday-rotation profiles for a range of simple helical-field models, and comparing these to some of the observed profiles.

- If something else in this talk has grabbed you, let me know!

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Imaging a Non-Relativistic Jet